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Pesticide Movement in Soils: A Comparison of No-Tillage and Conventional Tillage in the Beaver Creek Watershed in West Tennessee

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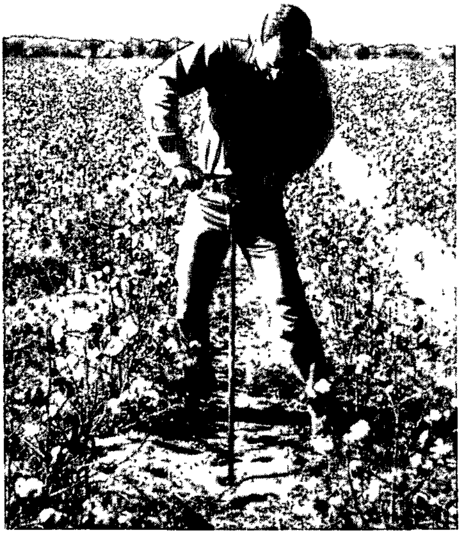

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Introduction

In 1989, the U.S. Geological Survey began a long-term project to evaluate the effectiveness of agricultural best management practices (BMP's) on controlling soil erosion and improving water quality in the Beaver Creek watershed in West Tennessee. The Beaver Creek watershed consists of about 95,000 acres and includes some of the Nation's most productive farmland and most highly erodible soils. Resource-management agencies in this locality have recommended conservation tillage or "no-tillage" as a BMP to control soil erosion.

Unlike conventional tillage, in which the top 1 foot of soil is turned over by a moldboard plow before planting, no-tillage preserves the natural structure of the soil and retains the crop residues from the previous growing season. No-tillage reduces soil erosion and runoff by slowing the flow of rainwater from the field. However, by preserving the macroporosity of the soil (by not tilling up old root channels and earthworm pathways), no-tillage has been found in some cases to accelerate chemical movement through the soil, increasing the potential for ground-water contamination (Dick and others, 1989; Hall and others, 1989; Isensee and others,1990).

The risk of ground-water contamination associated with the implementation of no-tillage needs to be addressed. Because the relation between no-tillage and chemical movement depends upon the climate and soils of a specific region, a field-level study was conducted to compare pesticide behavior in no-tilled and conventionally tilled soils in West Tennessee.

In 1993, the U.S. Geological Survey, in cooperation with the Tennessee Department of Agriculture, initiated an investigation of pesticide movement and degradation in soils. This fact sheet summarizes the goals of the study, the methods used, and the results of the pesticide analyses of the soil samples taken during the 1993 growing season. Additional details of this investigation are presented in Olsen and others, 1994.

Objectives

The objectives of this study were:

1. to develop a soil sampling strategy to accurately characterize the distribution of a selected pesticide in the soil profile,
2. to measure the movement and degradation of the pesticide throughout the growing season, and
3. to compare the behavior of the pesticide in no-tilled and conventionally tilled fields.

Pesticide Selection

The pesticide aldicarb was selected for this study because it is frequently used on cotton crops in this region and because it is both highly mobile and extremely toxic. Granular aldicarb is incorporated into the soil during planting, in bands centered along the row tops. Microbes in the root zone of the soil transform aldicarb into its highly toxic metabolites: aldicarb sulfoxide and aldicarb sulfone. Aldicarb and its metabolites eventually break down by natural, non-biological processes into relatively non-toxic end products.

Soil Sampling Strategy

Central to the study of pesticide movement and degradation is a sampling strategy that systematically addresses the spatial and temporal distribution of the pesticide within the soil profile. Pesticide movement may be influenced by the natural variations in the soil as well as by the patterns imposed by agricultural activities, such as pesticide application. A sufficient number of samples must be collected to obtain representative values. An insufficient characterization of the pesticide distribution may bias the comparison of no-tillage and conventional tillage.

To achieve an adequate characterization of the pesticide distribution over time and space, multiple sampling transects were used throughout the growing season. To account for the pattern caused by pesticide application, the transects were at right angles to the crop rows so that samples could be collected from the row top (where aldicarb was applied), the slope, and furrow positions (fig. 1).

Soil samples were collected in each position along the transect, in 0.5-foot depth intervals, using a stainless-steel bucket auger. Pesticide analyses were conducted by The Institute of Wildlife and Environmental Toxicology at Clemson University.

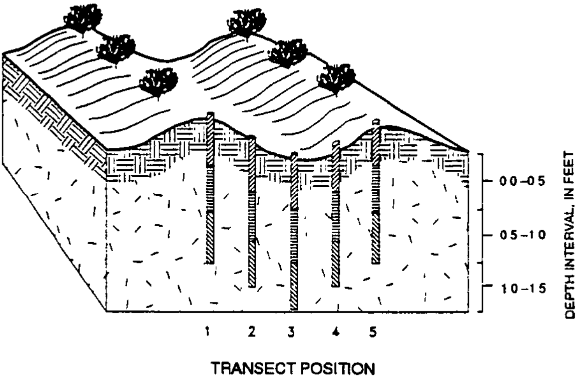

Figure 1. Schematic of the soil sampling strategy.

Results

The raw data from the pesticide analyses of the soil samples collected during the 1993 growing season from the conventional-till field and the no-till field were converted to concentration "maps." These maps were used to illustrate the extent of horizontal or vertical movement over time. The concentrations of aldicarb and its metabolites varied widely with time, depth, and transect position, ranging from <1.5 micrograms per kilogram (μg/kg) of soil (the detection limit) to 1,300 μg/kg for aldicarb sulfoxide 9 days after the date of application.

Because aldicarb has a short half-life (1 to 2 days), no aldicarb was detected in any samples after 9 days. Aldicarb sulfoxide, which is as toxic as aldicarb, was the predominant form of the pesticide throughout the study period.

Movement of Aldicarb Sulfoxide

In general, detection of aldicarb sulfoxide was limited to the row tops, where the pesticide was

applied. Aldicarb concentrations in the slopes and furrows were low or below the detection limit. This pattern across the sampling transects (fig. 2) was observed at all depth intervals, on all sampling dates, and in both the conventional-till and no-till fields. The non-occurrence of aldicarb sulfoxide in the slope and furrow positions indicates that horizontal movement was negligible in both fields (Olsen and others, 1994).

The variation in concentrations across the transects supports sampling in multiple positions within transects perpendicular to the orientation of the rows. Because the concentrations for a given position within the transect vary between transects, multiple transects are necessary to achieve field representation for that position.

In both the no-till and conventional-till fields, the peak aldicarb sulfoxide concentrations were found in the top 0.5 foot of soil throughout the growing season. Concentrations at the surface depth interval accounted for about 85 percent of the total aldicarb sulfoxide in the soil profile. Vertical movement in both fields was most likely limited by the low permeability of the silty-clayey soils, and by the low rainfall amounts and high rates of soil-water evaporation and plant transpiration during the summer months. Aldicarb sulfoxide was generally not observed below 2.5 feet in the conventional-till field, or below 1.5 feet in the no-till field. **No-tillage did not enhance vertical movement of aldicarb sulfoxide.**

Degradation of Aldicarb Sulfoxide

The term *half-life* refers to the time required for the concentration of a substance to decrease by one half. The degradation rates, or *half-lives,* of pesticides are derived from experimental data. Degradation rates are affected by environmental factors. Therefore, a particular pesticide can have variable rates of degradation. For this study, the half-lives of aldicarb sulfoxide calculated from the soil-concentration data were 15 days for the conventional-till field and 16 days for the no-till field.

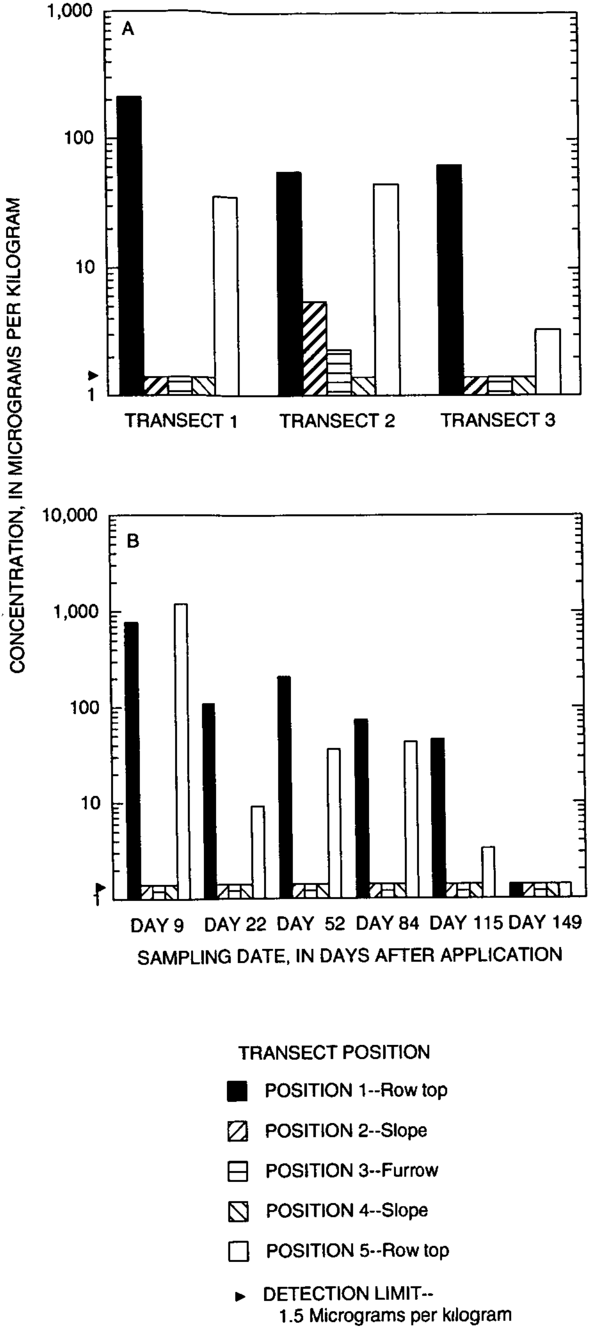

Figure 2. Distribution of median aldicarb sulfoxide concentrations (A) on day 52 in the conventional-till field by transect for the 0.0 to 0.5-foot depth interval and (B) as a function of time for selected transects.

Summary

The observed pesticide concentration distributions support sampling in multiple positions within transects perpendicular to the orientation of the crop rows. This sampling strategy provides a suitable data set for characterizing the movement of aldicarb and its metabolites through the soil profile.

Horizontal movement of aldicarb and its metabolites was negligible. Vertical movement of aldicarb and its metabolites was limited to the top 2.5 feet of soil. Most of the aldicarb residue (over 85 percent) remaining in the soil after 148 days was detected in the top 0.5 foot of soil.

No significant differences in the movement or degradation of aldicarb and its metabolites were observed between the no-tilled and conventionally tilled fields. No-till practices did not increase the downward movement of aldicarb in the test areas. No-tillage has proven to be an effective BMP for soil-loss reduction in many studies throughout the United States.

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Organizations involved in assessment studies in the Beaver Creek area:

U.S. Department of Agriculture, Natural Resources Conservation Service (formerly known as Soil Conservation Service)
U.S. Department of the Interior, U.S. Geological Survey
Tennessee Department of Agriculture
Tennessee Department of Environment and Conservation
Shelby County Conservation District
University of Tennessee Agricultural Extension Service
Clemson University
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